AERONOMY AND ASTROPHYSICS

Scientists stand outside the Degree Angular Scale Interferometer (DASI), the microwave detector at the Amundsen-Scott South Pole station on 6 January 2001. The detector was used by University of Chicago scientists and others to detect microwave evidence of the Big Bang in which the universe was thought to be created about 14 billion years ago.
(AP Photo, The Milwaukee Journal Sentinel, Ernie Mastroianni)

The polar regions have been called Earth's window to outer space. Originally, this term applied to dynamic events like the aurora, staged as incoming solar plasmas encountered the Earth's geomagnetic fields. Its unique properties create a virtual screen of the polar upper atmosphere on which the results of such interactions can be viewed (and through which evidence of other processes can pass). During the mid-1980s, Earth's window was extended to refer to the "ozone hole" in the polar atmosphere. As scientists have verified an annual loss of ozone in the polar stratosphere, a window previously thought closed (stratified ozone blocking the sun's ultraviolet rays) is now known to "open," consequent to chemical cycles in the atmosphere.

For astronomers and astrophysicists, the South Pole presents unique opportunities. Thanks to a minimum of environmental pollution and anthropogenic "noise," the unique pattern of light and darkness and the geomagnetic force field properties, scientists staging their instruments here can probe the structure of the Sun and the Universe with unprecedented precision. Studies supported by the Aeronomy and Astrophysics program explore three regions:

• **The stratosphere and the mesosphere:** In these lower regions, current research focuses on stratospheric chemistry and aerosols, particularly those implicated in the ozone cycle.

• **The thermosphere, the ionosphere, and the magnetosphere:** These higher regions derive many characteristics from the interplay between energetically-charged particles (ionized plasmas in particular) and geomagnetic/geoelectric fields. The upper atmosphere, particularly the ionosphere, is the ultimate sink of solar wind energy transported into the magnetosphere just above it. This region is energetically dynamic, with resonant wave-particle interactions, and Joule heating from currents driven by electric fields.

• **The galaxy and the Universe beyond, for astronomical and astrophysical studies:** Many scientific questions extend beyoud the magnetosphere, including a particular interest in the Sun and cosmic rays. Astrophysical studies are conducted primarily at Amundsen-Scott South Pole Station or on long-duration balloon flights launched from McMurdo Station. The capacity of such balloons is expanding dramatically.

All research projects sponsored by this program benefit from (indeed most require) the unique physical conditions found only in the high latitudes, yet their ramifications extend far beyond Antarctica. High-latitude astrophysical research contributes to the understanding of Antarctica's role in global environmental change, promotes interdisciplinary study of geosphere/biosphere interactions in the middle and upper atmosphere, and improves understanding of the critical processes of solar energy in these regions. Life exists on Earth in a balance because of numerous chemical and atmospheric phenomena that have developed in the specific atmosphere of this 4.6 billion year-old spinning planet, in orbit 149,637,000 kilometers around a middle-sized, middle-aged star. The 20th century expansion of traditional astronomy to the science of astrophysics, coupled with the emerging discipline of atmospheric science (See also the Ocean and Climate Systems program), is nowhere better exemplified than in Antarctica.

AMANDA - Antarctic Muon and Neutrino Detector Array.
Robert Morse, University of Wisconsin.

The AMANDA project takes advantage of unique polar conditions to discover and probe the sources - both within our galaxy and beyond - of the shower of very-high-energy neutrinos descending on (and usually passing through) the Earth. Neutrinos are elementary particles, believed to have very little or no mass and no electrical charge. Coursing through the universe, they are able to take any of three forms and interact only rarely with other particles. Thus they arrive at Earth with potentially unique information about where they may have originated. They could be diffuse (made up of contributions from many active galactic nuclei), perhaps even an indicator of the decomposition of the mysterious dark matter now believed to dominate the universe. Or they could be single sources - such as supernova remnants, rapidly rotating pulsars, the gas around black holes, neutron stars, or individual blazars.

AMANDA is the largest detector of neutrinos in the world. Over the last five seasons, the installation of over 600 photomultiplier tubes [embedded between 1 and 2 kilometers (km) into the ice, oriented downward] has established a natural detector of Cherenkov radiation in the ice. High-energy neutrinos that have sufficient energy to pass through the Earth's mass may collide with an atomic nucleus in the ice or rock near the tubes. Such collisions produce a distinctive eerie blue glow, which the basketball-sized glass tubes can detect for up to several hundred meters through the clear ice.

Previously, neutrino astronomy has been limited to the detection of solar neutrinos, plus one brief, spectacular burst from the supernova that appeared in the Large Magellanic Cloud in February 1987 (SN-1987a). In recent years, new sources of high-energy gamma rays have been discovered, such as the source Mrk-421, discovered by NASA's Compton Gamma-Ray Observatory and Mt. Hopkins Observatory. AMANDA is designed to study just such objects, which are believed to emit high-energy neutrinos copiously. Now that first-generation detectors such as AMANDA have been enhanced (the array may one day number 5,000 tubes strung on 80-some cables within one cubic km of ice) neutrino astronomy would appear to be on the verge of detecting high-energy particles that carry information from the outer edges of the universe. (AA-130-O)

Long-duration balloon project.
Danny Ball, NASA/National Scientific Balloon Facility.

As a means of high-altitude exploration, free-flying balloons possess many advantages over satellites. Balloons remain much longer in a specific location, cost a fraction to launch, and are designed to return their instruments safely to Earth. Balloons have been flying for two centuries, but until recently were limited by how long they could stay aloft. The latest scientific balloons, deployed from the National Scientific Balloon Facility (NSBF) in Palestine, Texas, are able to fly missions of 100 days or longer.

The current NSBF effort in Antarctica, known as the Long-Duration Balloon (LDB) program, launches high-altitude balloons carrying scientific payloads into the stratosphere. Many important scientific observations in fields such as hard x-ray/gamma-ray and infra-red astronomy, cosmic rays and atmospheric studies have been made from balloons.

This season the LDB program will focus on supporting the BOOMERanG project (See project AB-148-O). The Ultra Long Duration Balloon Project is an allied NSFB program which will provide launch support for the TIGER project (See project AB-149-O). (AB-145-O)

The Trans-Iron Galactive Element Recorder (TIGER).
Walter Binns, Washington University.

The Trans-Iron Galactive Element Recorder's (TIGER) maiden flight is scheduled for this austral summer. TIGER's complex stack of detectors are expected to retrieve the first measurements ever of high energy [greater than $3x10^8$ electron volts (eV) per nucleon] galactic cosmic rays with atomic numbers between 26 (iron) and 40 (zirconium) - so-called "ultra-heavy galactic cosmic rays." Such energy is believed to originate either in the interstellar medium or to have been freshly synthesized in supernovae. TIGER is expected to go a long way towards determining the source of the material that is accelerated as galactic cosmic rays and the mechanism for injecting that material into the cosmic-ray accelerator.

TIGER will be ferried by NASA's Ultra Long Duration Balloon (ULDB) Project, designed to push the limits of high-altitude, long-duration ballooning. These flights are planned for durations approaching 100 days, to make scientific observations at altitudes above 99 percent of the Earth's atmosphere. This inaugural ULDB balloon is pumpkin-shaped, about 80 by 130 meters and fabricated of polyester and polyethylene. Fueled by a super-pressured system of enclosed gas, the balloon doesn't carry the ballast that zero-pressure balloons need to compensate for day/night changes in pressure, and thus greatly expands the range and flight duration of these craft. TIGER's balloon will fly two revolutions around Antarctica between 77°S and 80°S, to ensure a long collecting time for galactic cosmic rays.

Included in the instrument array are 4 scintillation counters, 2 Cherenkov lightboxes, and a scintillating fiber hydroscope. The total scientific payload of 2200 pounds will require 800 watts of continuous power throughout the 12-hour days and nights. Internet communications will enable scientists to command the instrument and receive immediate data. Following the flight, we will recover the instrument and ship it back to the United States.

TIGER also serves as an engineering model of the ENTICE experiment, one of two instruments that make up the Heavy Nuclei eXplorer mission, recently selected by NASA for a Small Explorer Mission Concept Study. (AB-149-O)

The operation of an extremely-low-frequency/very-low-frequency radiometer at Arrival Heights, Antarctica.
A.C. Fraser-Smith, Stanford University.

Since it was discovered in the 1930s that natural phenomena emit the lowest form of electromagnetic energy - radio waves - the field of radio astronomy has joined the scientific effort to analyze both atmospheric and extraterrestrial signals. The ELF/VLF record of data collected by this project at Arrival Heights - chosen because it is unusually free from man-made electromagnetic interference - now extends unbroken for more than 13 years.

The radiometers at McMurdo operate in both the extra-low- and very-low-frequency (ELF/VLF) ranges, monitoring radio noise from natural sources such as thunderstorms. Characterizing the possible sources of radio interference is important for operational purposes. Since thunderstorm activity generates telltale radio signals, tracking variations in global noise reflects thunderstorm activity and thus can provide information on global climate change.

The Arrival Heights site is one of a network of eight such radiometers operated by Stanford University for the Office of Naval Research. (AO-100-O)

Magnetometer data acquisition at McMurdo and Amundsen-Scott South Pole Stations.
Louis Lanzerotti, University of Alaska Geophysical Institute, and Alan Wolfe,
New York City Technical College.

The magnetosphere is that region of space surrounding a celestial object (such as the Earth or the Sun) where the object's magnetic field is strong enough to trap charged particles. Magnetometers have been installed at selected sites in both polar regions to measure changes in the magnitude and direction of Earth's magnetic field. The unique climatic conditions in Antarctica also permit scientists to view the atmosphere optically (See project AO-104-O) and to correlate such hydromagnetic-wave phenomena with particle-precipitation measurements.

In this project we are measuring such variations with magnetometers installed at conjugate sites in both hemispheres; at McMurdo Station and Amundsen-Scott South Pole Station, Antarctica, and at Iqaluit in the Northwest Territories in Canada. The antarctic systems gather unique data related to the coupling of the interplanetary medium into the dayside magnetosphere, including the magnetospheric cusp region. The data also shed light on the causes and propagation of low-frequency hydromagnetic waves throughout the magnetosphere.

The antarctic magnetometers continue to measure the magnitude and direction of variations in Earth's magnetic field in the frequency range from 0 to about 0.1 hertz, with resolution of about one nanoTesla. These data are being analyzed in the context of other concurrent data acquired by the six U.S. automatic geophysical observatories (AGOs) that are a part of the Polar Experiment for Geophysical Upper Atmosphere Investigations (PENGUIn) program (project AO-112-0); and the data will also be ranged against data obtained from magnetometers operated by Bell Laboratories in the continental United States. (AO-101-O)

High-latitude magnetic pulsations.
Mark Engebretson, Augsburg College, and Roger Arnoldy,
University of New Hampshire.

The Earth's magnetic field arises from its mass and motion around the polar axis, but it creates a powerful phenomenon at the edge of space known as the magnetosphere, which has been described as a comet-shaped cavity or bubble around the Earth, carved in the solar wind. When that supersonic flow of plasmas emanating from the Sun encounters the magnetosphere, the result is a long cylindrical cavity, flowing on the lee side of the Earth, fronted by the blunt nose of the planet itself . With the solar wind coming at supersonic speed, this collision produces a "bow shock" several Earth radii in front of the magnetosphere proper.

One result of this process are fluctuations in Earth's magnetic field, called "micropulsations," which can be measured on time scales between 0.1 second and 1,000 seconds. It is known that magnetic variations can significantly affect power grids and pipelines. We plan to use magnetometers (distributed at high latitudes in both the antarctic and arctic) to learn more about how variations in the solar wind can affect the Earth and manmade systems.

We will study these solar-wind-driven variations and patterns at a variety of locations, and over periods of time up to a complete solar cycle. Since satellite systems are now continuously observing solar activity and also monitoring the solar wind, it is becoming feasible to develop models to predict the disruptions caused by such magnetic anomalies. And while our work is geared specifically toward a better understanding of the world and its manmade systems behavior, it will also involve space weather prediction. (AO-102-O)

Antarctic auroral imaging.
Stephen Mende, Lockheed Palo Alto Research Laboratory.

Scientists are only beginning to essay quantitative studies on the dynamic behavior of the magnetosphere. In the past, detail-oriented explorations with space satellites have enabled them to map the average distribution of magnetospheric energetic particle plasma content. But the dynamics of auroral phenomena - when particles from the magnetosphere precipitate into the atmosphere, producing fluorescence - have been hard to quantify through optical means. Amundsen-Scott South Pole Station is uniquely situated to observe aurora because the darkness of polar winter permits continuous optical monitoring; at most other sites, the sky becomes too bright near local mid-day.

The aurora can actually be regarded as a two-dimensional projection of the three-dimensional magnetosphere, because particles tend to travel along the magnetic field line. By observing the dynamics and the morphology of the aurora, scientists get a reliable glimpse into the dynamics of the region of the three-dimensional magnetosphere associated directly with it. This method relies on knowledge relating the type of aurora both to specific energies of precipitation as well as to specific regions of the magnetosphere.

We are deploying an intensified optical, all-sky imager (operating in two parallel wavelength channels, 4,278 and 6,300 Angstroms) to record digital and video images of auroras in the winter darkness. These wavelength bands allow us to discriminate between more- and less-energetic electron auroras and other precipitation. The South Pole Station observations of the polar cap and cleft regions entail measuring auroral-precipitation patterns and then interpreting the results in terms of the coordinated observations of (magnetic) radio-wave absorption images as well as (high-frequency) coherent-scatter radar measurements.

We expect this work to provide insight into the sources and energization mechanisms of auroral particles in the magnetosphere, as well as other forms of energy inputs into the high-latitude atmosphere. (AO-104-O)

Global thunderstorm activity and its effects on the radiation belts and the lower ionosphere.
Umran Inan, Stanford University.

Tracking dynamic storms is a challenge, but lightning associated with thunderstorms can provide scientists an indirect way of monitoring global weather. This project employs very-low-frequency (VLF) radio receivers at Palmer Station, Antarctica, operated in collaboration with the British and Brazilian Antarctic Programs, both of which operate similar receivers. All are contributors to the Global Change Initiative.

The VLF receivers measure changes in the amplitude and phase of signals received from several distant VLF transmitters. These changes follow lightning strokes because radio (whistler) waves from the lightning can cause very energetic electrons from the Van Allen radiation belts to precipitate into the upper atmosphere. This particle precipitation then increases ionization in the ionosphere, through which the propagating VLF radio waves must travel. Because the orientations to the VLF transmitters are known, it is possible to triangulate the lightning sources that caused the changes. Once the direction of the lightning source is known, it can be subjected to waveform analysis and used to track- remotely - the path of the thunderstorms.

The data will also be correlated with data from the antarctic Automatic Geophysical Observatory network, and will be used by scientists studying the magnetosphere and the ionosphere. (AO-106-P)

Extremely-low-frequency/very-low-frequency waves at the South Pole.
Umran Inan, Stanford University.

Atmospheric scientists orient their studies around different strata, or regions, and the boundaries and interactions between these regions are of particular interest. How are the upper atmosphere regions coupled electrodynamically? What can we learn by measuring the energy that is being transported between the magnetosphere and the ionosphere? These are but two of the questions the U.S. Antarctic Program's automatic geophysical observatory (AGO) program is designed to explore.

Plasmas occur in the magnetosphere and the ionosphere, and they can be transported and accelerated by a variety of different wave-particle interactions. One important dynamic in this system is particle precipitation that is driven by extra-low-frequency/ very-low-frequency (ELF/VLF) waves. Thus, measuring ELF/VLF waves from the multiple sites of the AGO network provides a powerful tool for remote observations of magnetosphere processes.

This project maintains a system at Amundsen-Scott South Pole Station to measure magnetospheric ELF/VLF phenomena and to correlate the data with measurements made by the AGO system. (AO-106-S)

Study of polar stratospheric clouds by LIDAR.
Alberto Adriani, Instituto De Fisica Dell'Atmosfera, Rome, Italy.

The appearance each spring of the stratospheric ozone hole above Antarctica is driven by chlorine compounds interacting on the surfaces of clouds that formed the previous polar winter, known as polar stratospheric clouds (PSCs). This is one explanation for why ozone depletion is much more severe in polar regions than elsewhere.

This project uses an optical radar (LIDAR, Light Detection And Ranging) to study the PSCs, stratospheric aerosol, and the thermal behavior and dynamics of the atmosphere above McMurdo Station. Continuous LIDAR observations provide insight on the formation, evolution, and other peculiar characteristics of these PSCs.

Such an observational activity is also performed in the frame of the Network for Detection of Stratospheric Change (NDSC), a global set of high-quality remote-sounding research stations for observing and understanding the physical and chemical state of the atmosphere (on the web at www.ndsc.ws). McMurdo Station is considered a primary NDSC site for LIDAR observations and for the monitoring of aerosol and clouds in the stratosphere. Such data also provide a complement to the information gained from balloon-borne instruments in project AO-131-O, and thus collaborative activities are being coordinated with the University of Wyoming. (AO-107-O)

A very-low-frequency beacon transmitter at the South Pole.
Umran Inan, Stanford University.

This 3-year project to establish and operate a very-low-frequency (VLF) beacon transmitter at South Pole will measure solar effects on Earth's mesosphere and lower ionosphere. Relativistic electrons - measured at geosynchronous orbit to have energies of greater than 300 kiloelectronvolts - appear to fluctuate in response to substorm and solar activity. During such events, these highly energetic electrons can penetrate as low as 30 to 40 kilometers above the Earth's surface. At that altitude, they can wreak havoc in the atmosphere - they ionize chemical species, create X-rays, and may influence the chemistry that produces ozone.

By comparing how the South Pole VLF signal varies in both amplitude and phase when it arrives at various antarctic stations, the extent of relativistic electron precipitation can be calculated. The transmitter will also produce other data as well - on solar proton events, relativistic electron precipitation from Earth's outer radiation belts, and on the Joule heating components of high-latitude/ polar-cap magnetosphere/ionosphere coupling processes.

VLF data from the South Pole beacon provides a valuable complement to two other efforts. First, to other antarctic upper atmospheric research, such as the Automatic Geophysical Observatory programs and the southern hemisphere coherent HF radar network Super4 Dual Auroral Network (SUPERDARN). Second, to ongoing satellite-based measurements of trapped and precipitating high-energy electrons at both high and low altitudes, the latter collected by the Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX). (AO-108-O)

South Pole Air Shower Experiment-2.
Thomas Gaisser, University of Delaware.

Cosmic rays consist of protons and other atomic nuclei, accelerated (scientists believe) to high energy levels in such distant astrophysical sources as supernova remnants. As cosmic rays from space arrive at the Earth, they interact in the upper atmosphere. The South Pole Air Shower Experiment-2 (SPASE-2) is a sparsely filled array of 120 scintillation detectors spread over 15,000 square meters at South Pole. This array detects the charged particles (primarily electrons) that are produced by interactions of these very high energy cosmic rays.

A nine-station subarray called VULCAN has been constructed to detect the Cherenkov radiation (light emitted by a charged particle moving through a medium at a higher speed than the speed of light within that material, analogous to the shock wave produced by objects moving faster than the speed of sound) produced high above the ground in the same showers. The SPASE array is located less than half a kilometer from the top of AMANDA and is designed to complement AMANDA's neutrino detecting capacity. (See project AA-130-OO). SPASE-2 has two goals:

First, to investigate the high-energy primary (galactic in origin) cosmic radiation, by determining the relative contribution of different groups of nuclei at energies greater than about 100 teraelectronvolts. This can be done by analyzing coincidences between SPASE and AMANDA. Such coincident events are produced by high-energy cosmic-ray showers with trajectories that pass through SPASE (on the surface) and AMANDA (buried 1.5 to 2 kilometers beneath it). AMANDA detects the high-energy muons penetrating the Earth in those same showers for which SPASE detects the low-energy electrons arriving at the surface. The ratio of muons to electrons depends on the mass of the original primary cosmic ray nucleus. The VULCAN detector further permits the calculation of two other ratios that also depend on primary mass in readings from the showers it detects.

Second, to use the coincident events as a tagged beam. This construction permits us to investigate and calibrate certain aspects of the AMANDA response. This project cooperates with the University of Leeds in the United Kingdom. (AO-109-O)

High-latitude Antarctic neutral mesospheric and thermospheric dynamics and thermodynamics.
Gonzalo Hernandez, University of Washington.

South Pole is a unique and interesting spot from which to observe the dynamical motion of the atmosphere. The fact that it is on the axis of Earth's rotation strongly restricts the types of wave motion that can occur there, as compared to lower latitude sites. Antarctica attracts atmospheric scientists for many reasons; a primary draw is that neutral winds perforce can only blow across the Earth's rotational axis. This simple condition has a profound influence on the large-scale dynamics of the atmosphere at high latitude, as only zonal wave-number one mode horizontal motions are possible.

The resulting simplifications may help in understanding the behavior of the global atmosphere. For example, how do scientists measure the wind speed of the atmosphere? One direct method is by determining the Doppler shift of naturally occurring emissions in the upper atmosphere as they flow along at predictable heights. Hydroxyl radicals (OH), for example, are confined to a fairly narrow band near 90 kilometers altitude.

This study uses a high-resolution Fabry-Perot interferometer (located at Amundsen-Scott South Pole Station) to make simultaneous azimuthal observations of the individual line spectra of several upper atmospheric trace species, most importantly the hydroxyl radical (OH) and atomic oxygen. The observed Doppler shift of the emission lines provides a direct measure of the line-of-sight wind speed, while the wind field structure can also be derived from these multi-azimuth measurements. The simultaneously observed line widths also provide a direct measurement of kinetic temperature. (AO-110-O)

Riometry in Antarctica and conjugate regions.
Theodore Rosenberg and Allan Weatherwax, University of Maryland.

We will continue our studies of the high latitude magnetic ionosphere and magnetosphere, using galactic radio-noise absorption techniques (riometry). Riometers measure the relative opacity of the ionosphere. We are using an imaging riometer system called IRIS (imaging riometer for ionospheric studies) that we developed several years ago; it is now being operated at Iqaluit, Canada; Sondestromfjord, Greenland; and South Pole and McMurdo stations, as well as in all six of the Automatic Geophysical Observatories (AGO) operated by the National Science Foundation in Antarctica.

We are also operating broad-beam riometers at Iqaluit, McMurdo, and South Pole, as well as auroral photometers at McMurdo and South Pole stations. We have helped to extend antarctic coverage by providing imaging riometers for the British Halley Bay and the Australian Davis stations. In the next few years we will build imaging riometers systems for some of the British AGOs. The instruments work synergistically with a number of other instruments that are operated at all of these sites by other investigators.

The focus of all of this work is to enhance understanding of the relevant physical processes and forces that drive the observed phenomena; this includes both internal (such as magnetospheric/ionospheric instabilities) and external forces, such as solar wind/IMF variations. From such knowledge may emerge an enhanced capability to forecast. Many atmospheric events can have negative technological or societal impact, and accurate forecasting could ameliorate these impacts. (AO-111-O)

Polar experiment network for geophysical upper-atmosphere investigations (PENGUIn).
Theodore Rosenberg, University of Maryland at College Park.

The data obtained from automatic geophysical observatories (AGO) help researchers understand the Sun's influence on the structure and dynamics of the Earth's upper atmosphere. The ultimate objective of this research into how the solar wind couples with the Earth's magnetosphere, ionosphere, and thermosphere is to be able to predict solar/terrestrial interactions that can interfere with long-distance phone lines, power grids, and satellite communications.

A consortium of U.S. and Japanese scientists are working with a network of six AGOs, established on the east antarctic polar plateau and equipped with suites of instruments to measure magnetic, auroral, and radiowave phenomena. The AGOs are totally autonomous, operate year-round, and require only annual austral summer service visits.

When combined with measurements made at select manned stations, these arrays facilitate studies on the energetics and dynamics of the high-latitude magnetosphere, on both large and small scales. The research will be carried out along with in situ observations of the geospace environment by spacecraft, in close cooperation with other nations working in Antarctica, and in conjunction with conjugate studies performed in the Northern Hemisphere. PENGUIn AGO data will be sent to Augsburg College in Minnesota to be processed and distributed to PENGUIn investigators. (AO-112-O)

Auroral dynamics by the all-sky-imager at Amundsen-Scott South Pole Station.
Masaki Ejiri, National Institute of Polar Research, Japan.

The South Pole is a unique platform for observing aurora during austral winter season. As a point on the Earth's rotational axis, the pole provides a unique vantage to observe the airglow and to discern the characteristics of acoustic gravity waves in the polar region, as they vary in altitude and wavelength. We can observe aurora continuously throughout the 24 hours in a day, which allows us to collect data on:

• the dayside polar cusp/cleft aurora (due to the direct entry of the solar wind);

• afternoon aurora that are closely associated with the nightside magnetospheric storm/substorm activities; and

• the polar cap aurora, which is dependent on the polarity of the interplanetary magnetic field.

Research has shown that these auroras develop from precipitating low-energy particles entering the magnetosphere from the solar wind.

Though data have been acquired at the South Pole since 1965 using a film-based, all-sky camera system, newer technology now produces digital images and permits us to process large amounts of information automatically. Currently, we are using the all-sky-imager (ASI), a digital CCD imager monitored and controlled by the Japanese NIPR (National Institute of Polar Research).

These international collaborations should enhance knowledge of the magnetosphere, the ionosphere and of upper/middle atmosphere physics. The HF (high frequency) radars at Halley Bay, Sanae, and Syowa Station provide the vector velocity of ionospheric plasma over the South Pole. These studies should provide further insight into the physics of the magnetosphere, the convection of plasma in the polar cap, and solar wind effects - specifically dayside auroral structure, nightside substorm effects, and polar-cap arcs. (AO-117-O)

Solar and heliosphere studies with antarctic cosmic-ray observations.
John Bieber, University of Delaware.

Cosmic rays - penetrating atomic nuclei and electrons from outer space that move at nearly the speed of light - continuously bombard the Earth. Colliding with nuclei of molecules found in the upper atmosphere, they create a cascade of secondary particles that shower down toward Earth. Neutron monitors deployed in Antarctica provide a vital three-dimensional perspective on this shower and how it varies along all three axes. Accumulated neutron-monitor records (begun in 1960 at McMurdo Station and in 1964 at Amundsen-Scott South Pole Station) provide a long-term historical record that supports efforts to understand the nature and causes of solar/terrestrial and cosmic-ray variations, as they are discerned occurring over the 11-year sunspot cycle, the 22-year Hale cycle, and even longer time scales.

This project continues a series of year-round observations at McMurdo and Amundsen-Scott South Pole Stations, recording cosmic rays with energies in excess of 1 billion electronvolts. These data will advance our understanding of a number of fundamental plasma processes occurring on the Sun and in interplanetary space. At the other extreme, we will study high time-resolution (10-second) cosmic-ray data to determine the three-dimensional structure of turbulence in space, and to elucidate the mechanism by which energetic charged particles scatter in this turbulence. (AO-120-O)

Effects of enhanced solar distrubances, during the 2000-2002 solar-max period, on the antarctic mesophere-lower-thermosphere (MLT) and F regions composition, thermodynamics, and dynamics.
Gulamabas Sivjee, Embry Riddle Aeronautical University.

While variations in the Sun's energy affect people in obvious ways - driving the weather and the seasons - there are actually many cycles and variations of deeper interest to science, on scales from seconds to centuries to eons. One of the most basic is the 11-year cycle when the Sun's magnetic poles reverse direction (the 23rd of which - since reliable observations began - has just recently peaked), and sunspots and other solar activity wax to peak levels. NASA is using this opportunity to conduct its TIMED (Thermosphere-Ionosphere-Mesosphere-Energetics and Dynamics) satellite study, which will focus on the region between 60 and 180 kilometers above the Earth's surface.

Taking advantage of the timing of both of these events, we will use observations in the visible and near-infrared ranges of upper-atmospheric emissions above South Pole Station to study the heating effects of auroral electrical currents in the ionosphere, as well as planetary waves and atmospheric tides.

TIMED will provide data on the temperature, winds, and tides of Earth's upper atmosphere, especially above the poles as it passes overhead. But tracking satellites often have difficulty differentiating between variations in location or time. The South Pole ground-based observations will be valuable in sorting out the time-location question. (AO-129-O)

Measurements of polar stratospheric clouds, condensation nuclei, and ozone during the austral winter and spring.
Terry Deshler, University of Wyoming.

We are continuing a series of observations to characterize the particles in polar stratospheric clouds (PSCs; known to be critical to ozone depletion) and will make additional observations that may provide the first indications of ozone recovery. Using balloon-borne instruments, we will take PSC particle-size distribution measurements during the early- and mid-winter period (when PSC activity is greatest), and during late winter, when ozone loss begins. The ozone measurements will begin in late August and continue through October.

The fundamental measurements from the PSC instruments provide estimates of the size and concentration of the particles that form in these clouds. Heterogeneous chemistry - which activates chlorine so that it can then destroy ozone - occurs on the surface of these particles. From such measurements one can estimate the volume of PSCs, as well as their surface area.

These results help scientists to:

• quantify existing models for chlorine activation and ozone loss models;

• calculate denitrification/dehydration rates; and

• estimate particle composition.

We are also estimating the composition of particles by inferring their index of refraction, through continuing collaboration with the McMurdo LIDAR measurements of Alberto Adriani, Istituto di Fisica Dell'Atmosfera, Rome (See project AO-107-O).

In addition to the aerosol measurements, we will continue to develop annual profiles of the ozone in late winter and spring, when stratospheric chlorine levels are peaking. This provides (at a minimum) a measurement base to detect the first signs of ozone recovery. As the season warms, ozone depletion falls off and is expected to be altitude-dependent. Such vertical ozone profiles provide one of the crucial tools needed to observe the first signs of recovery following the decline in stratospheric chlorine. These measurements are archived in the data base of the Network for the Detection of Stratospheric Change. (AO-131-O)

Dynamics of the mesophere and lower thermosphere using ground-based radar and TIMED instruments.
Susan K. Avery, University of Colorado, Boulder.

This is a propitious time to study a number of atmospheric phenomena, because of the recently-peaked 11-year solar cycle, and NASA's TIMED satellite mission (See project AO-129-O). In addition to measurements derived from instruments on TIMED, we are installing a meteor radar at Amundsen-Scott South Pole Station. Concentrating on the dynamics of the mesosphere and lower thermosphere, we are looking at:

• the space-time decomposition of wave motions;

• delineation of the spatial climatology over Antarctica with emphasis on the structure of the polar vortex;

• dynamical response to energetic events; and

• inter-annual variability.

The proposed meteor radar is a VHF system capable of measuring the spatial structure and temporal evolution of the horizontal wind field over the South Pole. Spatial climatology data will also come from existing ground-based radars at Davis Station, Syowa Station, Rothera Station, and the Amundsen-Scott base.

As NASA's TIMED satellite orbits over the South Pole, wind and temperature data will provide counterpoint and corroborative information. Thus, experiments based both in space and on the ground may be mounted, and data that was previously reliant on a single source can be better validated. (AO-284-O)

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